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Request for grant of a patent

The Patent Office
Cardiff Road
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1. Your reference

1893401/DJBB

2. Patent Application Number

0300291.2 -7 JAN 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Sensopad Technologies Limited
Harston Mill
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815747001

Patents ADP number *(if known)*

If the applicant is a corporate body, give the country/state of its incorporation

Country: **England**
State:

4. Title of the invention

POSITION ENCODER

5. Name of agent **Beresford & Co**

"Address for Service" in the United Kingdom to which all correspondence should be sent

2/5 Warwick Court
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London WC1R 5DH

Patents ADP number 1826001

6. Priority details

Country	Priority application number	Date of filing

Patents Form 1/77

7. If this application is divided or otherwise derived from an earlier UK application give details

Number of earlier application | Date of filing

8. Is a statement of inventorship and or right to grant of a patent required in support of this request?

Yes

9. Enter the number of sheets for any of the following items you are filing with this form.

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Description	**15**
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Drawing(s)	6 + 6

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Priority documents	
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Statement of inventorship and right to grant of a patent *(Patents form 7/77)*	1 + 3 copies
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11. I/We request the grant of a patent on the basis of this application

Signature Beresford & Co
BERESFORD & Co

Date 7 January 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

DAVID BRINCK

Tel: 020 7831 2290

POSITION ENCODER

FIELD OF THE INVENTION

This invention relates to position encoders generally, and has particular but not exclusive relevance to linear, rotary and radius encoders. The invention has particular although not exclusive relevance to man-machine interfaces where position information is used as a method of data entry.

DISCUSSION OF THE PRIOR ART

Many types of position sensor have been proposed. The same applicant has described a sensor system similar to the present invention in UK Patent Application GB 2374424A, whose contents are hereby included here by reference. This describes a sensor that generates electrical signals indicative of the position of two relatively movable members. The relative movement is defined as a displacement or velocity of a first member along or around the measurement axis of a second member. The first member includes an inductive target, which carries an intermediate electrical device or circuit and the second member includes an aerial, which carries excitation and sensor windings. The intermediate electrical device may be a conductive disk but most advantageously is a resonant circuit made from an inductor and a capacitor in electrical series. Typically the target moves in a plane substantially parallel to the aerial's plane. The magnetic coupling between the target's resonant circuit and the aerial's sensor windings varies with position. By applying an AC voltage at the intermediate circuit's resonant frequency to the excitation windings, a signal is induced in the aerial's sensor winding indicative of

the relative position of the two members. The sensor's excitation frequency is modulated at a much lower frequency (typically about 1% of the excitation frequency) to enable signal processing by simple low-cost digital electronics.

One feature of such a sensor is that measurement of the target's position along the measurement axis is largely independent of the distance measured normally between the planes of the target and aerial provided that the target remains within the aerial's range.

Such a sensor is advantageous in many instances but can place undesirable constraints on the design of the sensing system. Specifically with such a sensor the target must move along the measurement axis and must carry an electrical intermediate device such as a resonant circuit or conductive element. Often the object whose position is to be measured may not be suitable to carry an electrical intermediate device, for example when it is required to measure the position of a person's fingers acting as a means of data entry in man-machine interface applications. Furthermore, it is often required to have electrical contact free sensing where z-axis motion is indicative of the position to be measured, for example in man-machine interfaces as a method of data entry or in sports training facilities where the impact point of a ball upon a plane is to be measured.

SUMMARY OF THE INVENTION

In one aspect the invention provides a method and apparatus for indicating a position using an arrangement of excitation, intermediate and sensor windings which provide a signal whose amplitude or phase is indicative of the distance, along a

measurement direction of the sensor, where the intermediate winding is deformed obliquely or perpendicularly to the plane of the excitation and sensor windings, wherein the intermediate circuit is fixed relative to the excitation and sensor windings along the measurement direction. In an embodiment, at least one of the excitation or sensor windings comprises at least one conductor having a first portion extending away from a position on the measurement axis in a pattern of sinusoidal windings and a second return portion having similar convolutions, the convolutions of the first and second portions being substantially 180 degrees out of phase.

In another aspect the invention provides an apparatus for indicating a position using an arrangement of excitation and sensor windings which provide an electrical signal whose amplitude or phase is indicative of the distance, along a measurement direction of the sensor, where the first excitation or sensor winding, is deformed obliquely or perpendicularly to the plane of the second sensor or excitation winding, wherein the first winding is fixed relative to the second winding along the measurement direction and wherein at least one of the excitation or sensor windings comprises at least one conductor having a first portion extending away from a position on the measurement axis in a pattern of sinusoidal windings and a second return portion having similar convolutions, the convolutions of the first and second portions being substantially 180 degrees out of phase.

The present apparatus has a wide variety of applications in position measurement systems, electronic controls and user interfaces in automotive

vehicles, domestic appliances, medical equipment, aerospace equipment, agricultural equipment, industrial machinery, ships, textile machinery, sports equipment, audio-visual equipment, defence equipment, IT/communications equipment, PC's, security systems etc. One noteworthy application for the two-dimensional form of the sensor is monitoring patients in bed as a preventative measure against pressure sores or as a security system used to monitor a baby's motion in a cot.

BRIEF DESCRIPTION OF THE DRAWINGS

How the invention may be put into effect will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a section of the excitation windings, intermediate circuit, sensor windings and housing along the measurement axis;

Figure 2 shows the layout of the excitation windings, intermediate circuit and sensor windings in plan view;

Figure 3 shows the layout of the excitation windings, intermediate circuit and sensor windings for one array of a two-dimensional sensing arrangement;

Figure 4 shows an arrangement of an interchangeable fascia panel co-operating with the sensor;

Figure 5 shows an arrangement of excitation windings, sensor winding and an intermediate resonant circuit which may be used for accurate but unambiguous position sensing over extended distances.

Figure 6 shows in section an alternative embodiment of the invention comprising layered windings.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The sensor is shown in section in Figure 1. The sensor comprises a fixed but deformable target [1] comprising an intermediate circuit, a mechanical housing [2] and a fixed aerial [3] containing excitation and sensor windings that co-operate with an electronic system. The electronic system chiefly comprises signal generation, receive and signal processing subsystems.

A plan view of the sensor's aerial and intermediate resonant circuit is shown in Figure 2. Advantageously the aerial contains excitation windings made from one or more sine [4] and cosine [5] windings arranged in space quadrature such that EMF's in adjoining loops oppose each other and a sensor winding [6] which generally extends around the excitation windings which may or may not be electromagnetically balanced to far field emissions. It should be noted that each of the windings is electrically insulated from the others either by means of an insulating layer around the conductors or by virtue of the conductors being on opposing sides of multi-layer printed circuit boards.

Advantageously the intermediate circuit [7] is a passive LC resonant circuit which is fixed relative to the aerial in the measurement direction but which can deform normally to the aerial under the influence of an external force. The coil of the intermediate circuit generally extends fully along the sensor's measurement axis and is arranged such that when no external force is applied, the sensor is substantially electro-magnetically balanced with respect to the excitation

windings and consequently there is little or no measurement signal.

The intermediate electrical circuit and the aerial are fixed in a mechanical housing [3] which also physically separates the intermediate circuit from the excitation and sensor windings. Although not a preferred design it is possible that the excitation windings, intermediate circuit and sensor winding are in a single plane when particularly thin section sensors are required.

The frequency generation circuit contains an electrical power supply capable of generating AC signals in the excitation windings of various frequencies in the range of the intermediate circuit's resonant frequency. Advantageously, AC signals in phase quadrature at substantially the resonant frequency of the intermediate circuit are applied to each of the excitation windings. The resulting magnetic field approximates to a rotating vector field along the measurement axis. When an external force ios applied to cause a localised deformation of the intermediate circuit, that portion of the intermediate circuit experiences an increase in electro-magnetic coupling to the magnetic field. The alternating magnetic field induces an AC current to flow in the intermediate resonant circuit. In turn this current further induces a voltage in the sensor winding. The amplitude or phase of this signal is indicative of the position of deformation.

One example from various electronic and processing algorithms is one in which the frequency generation circuit generates oscillating signals in the excitation windings in time quadrature - given by $\sin(w_0 t)$ in the

sine coil and $\cos(w_0 t)$ in the cosine coil. This produces a composite signal given by:

$$\sin(w_0 t)\sin(2.PI.X/L) + \cos(w_0 t)\cos(2.PI.X/L)$$

where X is the distance of the deformation of the intermediate circuit along the transmit windings and L is the wavelength of the winding pattern.

The intermediate circuit induces a signal in the sensor winding whose phase is at -90 degrees to the alternating field produced by the combination of fields from the sine and cosine circuits. The phase of the received signal is proportional to the distance X along the excitation windings. The signal received by the sensor winding is of the form:

$$A.\cos(w_0 t-(2.PI.X/L))$$

In the above equation, A represents a gain due to the resonator, and 2.PI.X/L represents a phase shift relative to the original excitation signal. This phase shift is readily measured using zero crossing electronics.

Hence X may be calculated from the phase of the received signal. This calculation applies when the resonant circuit exactly matches the excitation frequency and induces a signal exactly lagging by -90 degrees. However, in most instances there will be a slight mismatch in the excitation frequency and the actual resonant frequency. This mismatch will cause a phase error. Such errors may be caused by temperature changes, inexact capacitor or inductor values in the resonant circuit or other changes in the system. This

error may be removed by performing a second measurement with a reversed signal fed in to either the sine or cosine coil and averaging the two measurements to cancel any errors.

Advantageously excitation frequencies in the range 100 kHz to 10 MHz are used. Advantageously the induced signal in the sensor windings will be 180 out of phase with the excitation signals thus providing the sensor with good signal to noise ratios.

The excitation, sensor and intermediate circuits may advantageously be produced using printed circuit board techniques in which conductive tracks are laid down by direct printing or photo-lithography methods on to insulating substrates. Of particular relevance is the use of thick film or screen-printed conductive inks on to flexible substrates such as polyester. Such conductive inks typically comprise a significant proportion of silver or copper and are often used in the production of PC keyboards. Equipment used to produce such circuits is capable of printing conductive tracks interspersed with non-conductive dielectric layers which enables cost effective multi-layer constructions necessary for the looped sine and cosine type windings necessary for this sensor.

Multi-layer printing of conductive and dielectric layers may be advantageously used to print the capacitor of the intermediate resonant circuit. Capacitors of various values and hence intermediate circuits of various resonant frequencies can be readily printed by the same methods. Various capacitance values may readily be achieved by varying the area and/or thickness of the printed conductive and

dielectric sandwich which is connected in series with the intermediate circuits inductor.

Such multi-layer printing as well as profile cutting methods can also advantageously print graphics and text on the top surface of such constructions when such sensors are used in man-machine interfaces. Light emitting diodes may also be readily assembled in to such constructions. Insulating materials used to separate the intermediate circuit from the aerial are readily available as relatively standard polymers such as polyester or polyamide. These materials are often used for similar mechanical construction techniques in membrane switch assemblies. Cavities may be cut from such material using traditional knife techniques, laser or water jet cutting. Adhesive layers may also be printed on the underside of such sensors to aid fixing to mechanical assemblies such as moulded or fabricated fascia panels.

MODIFICATIONS & FURTHER EMBODIMENTS

It will be obvious to those skilled in the art that deformation of the excitation and sensor windings towards the intermediate circuit is equivalent to deformation of the intermediate circuit towards the excitation and sensor windings.

The sensor assembly and production methods have much in common with traditional membrane switch production methods. Unlike membrane switches, which typically provide simple circuit make or break signals, the sensor provides analogue type measurement. This is particularly advantageous. For example, in a membrane switch style user interface a user must push a switch

several times or hold it down for an extended period in order to set a desired speed or volume. With this sensor the user simply presses the part of the sensor corresponding to the desired value. Indications may simply be printed on the top surface of the sensor. Such a sensor also offers a cost effective, simple and low profile alternative to the usual rotary dial or linear slide encoders which are most typically used for setting a control parameters such as volume, speed etc.

Given the commonalities of the sensor's construction methods with membrane switches, such switches may be cost effectively deployed in conjunction with the sensor if desired. Alternatively, a single point sensor may be used to replace such membrane switches where water, foreign material or lifetime problems prevents reliable deployment of membrane switches. Furthermore a series of single point measurements can be configured along one sensor which extends over the length of the series.

Membrane switches also require a dome to produce contact and separation of the switches electrical contacts. No such dome is required for the sensor although such constructions may be deployed for tactile or mechanical support reasons if it is necessary to provide support between the aerial and the intermediate circuit. Alternatively an elastic material such as foamed rubber or neoprene may be used between the intermediate circuit and the aerial to support the intermediate circuit. Such constructions advantageously provide the user with a firm tactile feel.

Sensors can range in scale of a few mm to several metres or more. Sensors may be configured to sense

over many different geometries including linear, rotary, curvi-linear, two-dimensional etc. Two-dimensional sensors may be constructed in a number of ways. Firstly linear sensors may simply be repeated so as to form an array of linear sensors in one axis as shown in Figure 3. Each sensor provides a measurement of deformation in its measurement axis and a value indicating position at 90 degrees to the measurement axis can be indicated by the number attributed to the sensor providing the reading. Secondly two arrays of linear sensors may in both X and Y directions may be used. Thirdly a linear sensor may be wrapped in a zigzag or in a spiral so as to form a two-dimensional area.

In instances where the sensor is required to sense position over an extended period with high accuracy this can be achieved by the use of multiple wavelengths of the excitation windings. Such an arrangement is shown in Figure 5 in which windings 4a and 5a are the fine pitch sine and cosine windings co-operating with the coarse pitch sine and cosine windings 4 and 5 respectively. Unambiguous position sensing may still be obtained with the use of a single wavelength of excitation windings extending over the length of the multiple wavelengths. The signal received by the sensor coils is a combination of the fine pitch yet ambiguous signal and the coarse pitch unambiguous signal, from which an accurate position measurement can be made.

Multiple sensors may be controlled using a single set of multiplexed electronics in order to minimise costs. The same electronics may also be used to control sensors of the more traditional type as

described in GB 2374424A where the target moves relative to the aerial along the measurement axis. Such sensors can be used alongside or directly with this invention. When used directly with this invention the moving resonant target is of one frequency while the fixed target is of a different frequency. The combined sensor's drive and receive electronics switches intermittently between the two frequencies in order to obtain a signal indicative of the position of the moving target and of the position of the deformation of the fixed target. Traditional techniques measure the position of the first target relative to the fixed aerial. This invention measures the deformation of the fixed target relative to the same fixed aerial. This position could be the point at which the moving target is pressed towards the aerial. This technique is particularly advantageous for user interfaces in automobiles and domestic appliances, for example, which require a combination of both techniques.

Advantageously the surface plane containing the intermediate electrical circuit is mechanically and electrically detachable from the surface plane containing the aerial. This enables easy customisation of a control system to a particular type of user interface. An illustration is shown in Figure 4. The pattern or layout of an interface is electronically attributed in software to a frequency or position of a passive resonant circuit attached to the detachable unit. The corresponding aerial and associated electronics may detect the resonant circuit's frequency or position signature and hence configures or parameterises the controlling software such that the

identity and format of the interface may be set. From such information other control parameters of the host's system, for example a washing machine, can be configured. This is particularly advantageous in allowing manufacturers to customise products late in the supply chain and hence simplify and reduce the high logistics costs normally associated with the supply of a wide variety of (slightly) different products.

No stylus is required for the two-dimensional form of this invention as with many other forms of two-dimensional sensing - a user's finger will suffice. Unlike the capacitive based touch pads used with PC's this invention is robust in harsh environments and insensitive to water, humidity or temperature drift. Stylus free signature verification and writing recognition are applications of this sensor.

In order to minimise costs the excitation windings, sensor windings and intermediate circuits may simply be produced with wire wound structures where no supporting substrate is required.

Screen overlays to enable touch screen sensing are an important application for such sensors where the advantages of robust performance in harsh environments may be utilised. In such an application the wires used in the intermediate circuit should preferably be of as small a gauge as possible in order not to detract from the image quality of the screen. Furthermore, the aerial may be placed beneath the screen in order not to detract from the image quality of the screen.

When the length or area of deformation is large an average value of the dimension is produced.

When multiple deformations are present an intermediate value will be produced.

The sensor may be simplified by eliminating the intermediate electrical circuit and replacing the sensor coils in its place.

Ease of deformation of the intermediate circuit by a user may be assisted by the use of convex or concave structures similar to those used in membrane switches but extended over the measurement axis.

Rather than deformation of the intermediate circuit towards the aerial by an external forces a reading may also be obtained when the sensor assembly bends such that the point at which the sensor creases is the measured position.

For purposes of simplicity, the embodiment above is described using simple sinusoidal excitation at the frequency of the resonant circuit. Alternatively, excitation signals may be provided where each excitation signal consists of a carrier signal at the frequency of the resonant circuit, modulated by a lower frequency modulation signal (typically a few kHz), wherein the modulation signals for the excitation circuits are in phase quadrature. The signal received at the sensor winding is then demodulated to obtain a signal at the lower frequency whose phase depends on the parameter being measured. This excitation method has the advantages of obtaining high electromagnetic signal coupling due to the high carrier frequency, and low-cost electronics due to the lower time resolution required to make a zero-crossing measurement of the lower-frequency received signal.

It will be obvious to those skilled in the art that the excitation signals need not be sinusoidal, and that various different periodic excitation signals may be employed. For instance, pulse width modulation

(PWM) and pulse-position modulation (PPM) are two commonly-used schemes often employed in sensors of this type.

A further sensor embodiment is shown in figure 6. The diagram shows the layout of the sensor in section. In this embodiment the amount of deflection normal to the plane of an antenna 8 of a portion of intermediate circuit 9 is measured. The antenna contains excitation and receive windings formed from conductors 10 arranged on a plurality of layers. Sine and cosine windings are each formed from loops on a plurality of layers and connected such that the electro-magnetic field from each varies sinusoidally with position in the Z direction. The fields from the sine and cosine windings are arranged to be substantially in space quadrature. When the sine and cosine windings are energised using phase quadrature signals at the frequency of the resonant intermediate circuit, a signal is received at the sensor winding whose phase varies with the position to be measured. It is anticipated that this embodiment may be readily constructed using a multi-layer printed circuit board or alternatively by any of the manufacturing techniques described above.

Figure 1

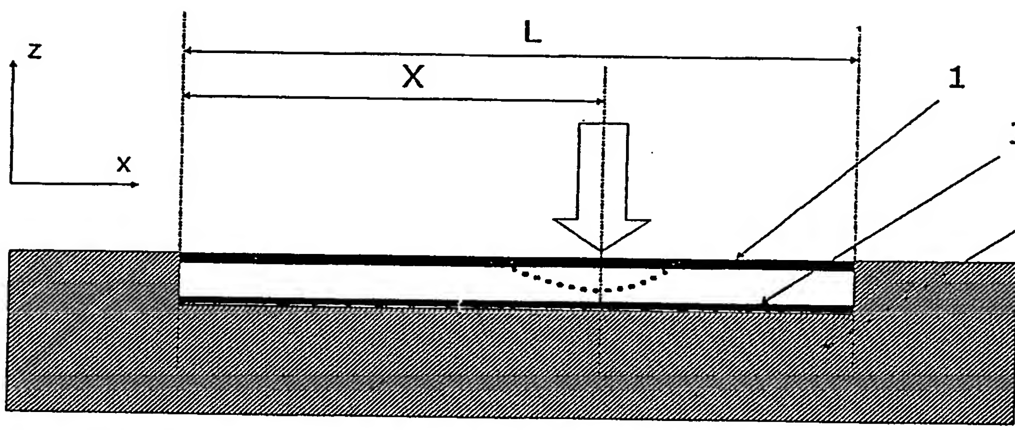

Figure 2

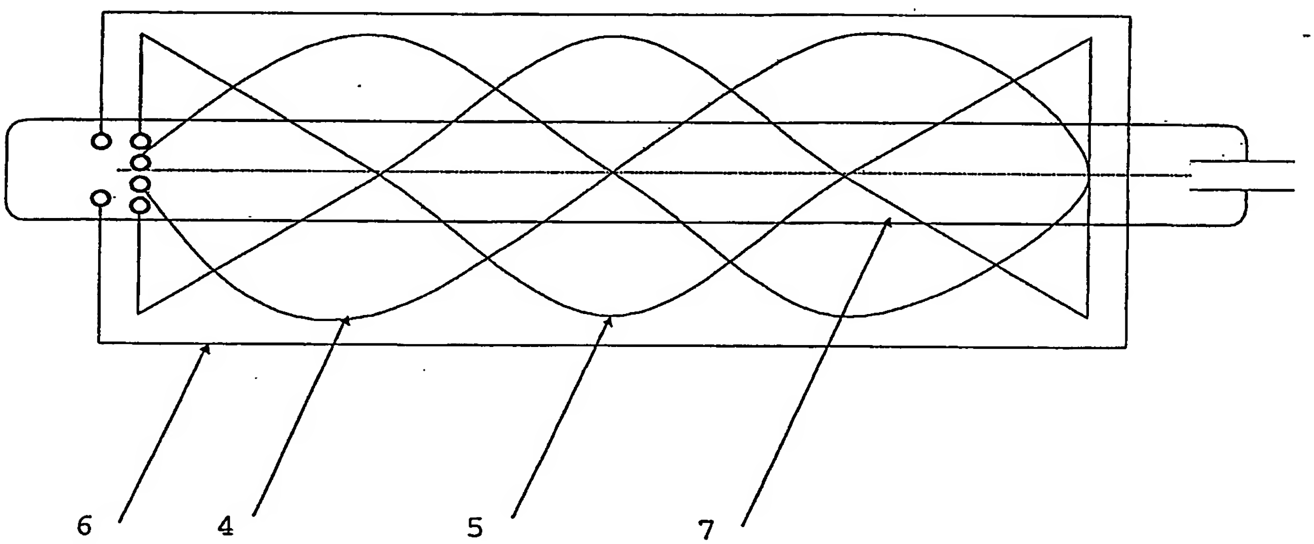

Figure 3

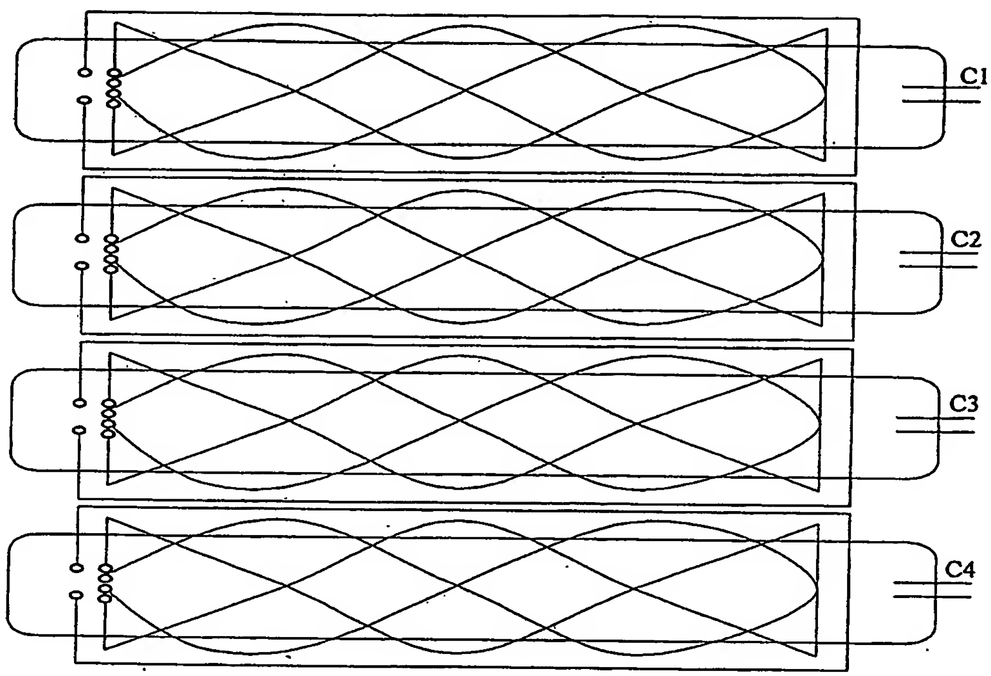

Figure 4

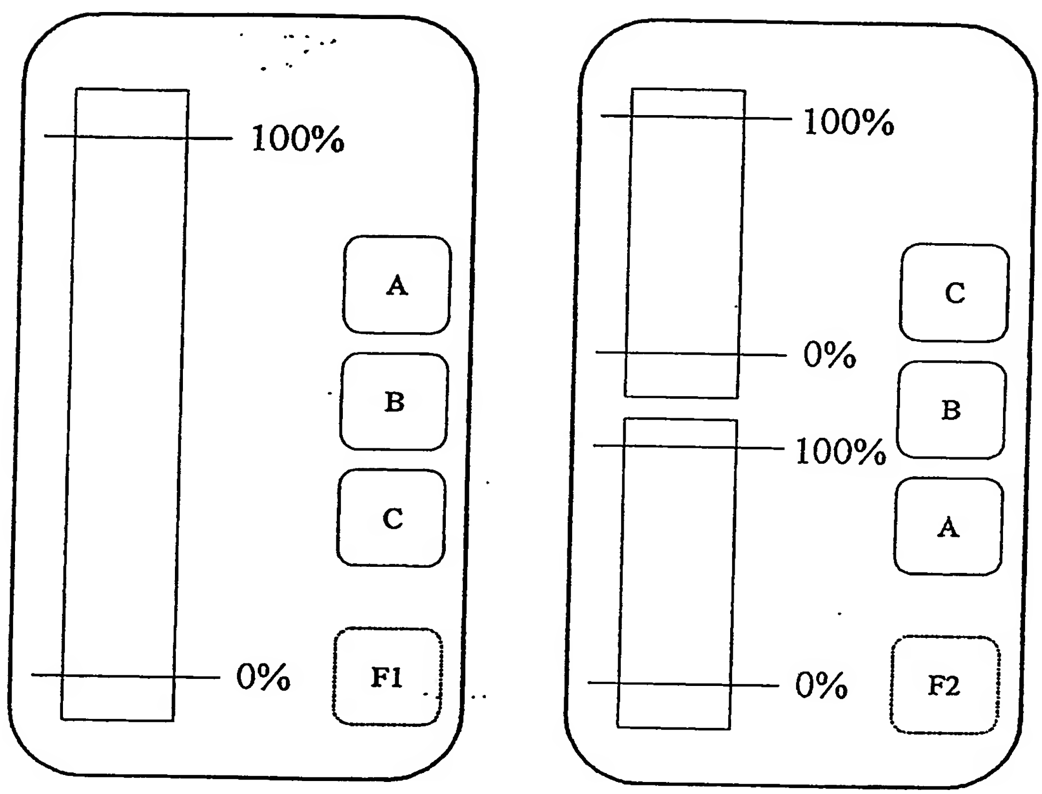

Figure 5

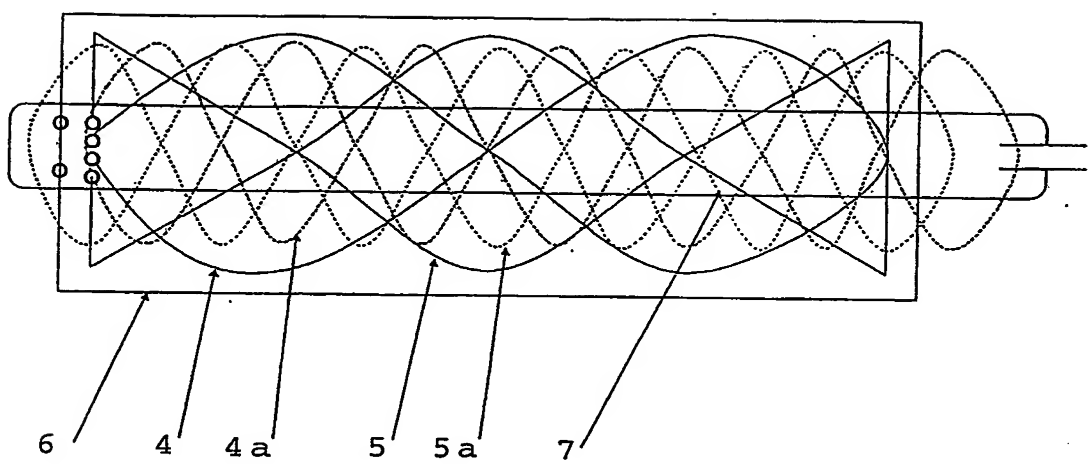

Figure 6